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# Pricing in inflationary times: The penny drops

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ABSTRACT

How does the frequency and magnitude of micro-price rises and falls relate to macroeconomic crisis, as well as moderation? Weekly micropricing behaviour in British groceries was investigated across three leading retailers over the moderation period 2004–7 and the crisis period 2008–10. We find significant price flexibility sharply distinguished from behaviour observed in most previous works. Downward price flexibility increased markedly in 2008. Overall basket prices rise, but significantly more individual prices fall than rise in the latter period. Tests of obfuscation in price setting suggested that large numbers of small price falls were used to disguise the basket price rises.



## 1. Introduction

A key question faced by policymakers, forming monetary policy to meet an inflation target, is how firms set nominal prices, especially in response to shocks (Eichenbaum et al., 2011; Kehoe and Midrigan, 2014). Micropricing studies with implications for macro-modelling have been surveyed by Alvarez (2008), Klenow and Malin (2011) and Nakamura and Steinsson (2013) amongst others, but the focus is largely on the moderation period. We examine how the frequency and magnitude of micro-price rises and falls relate to macroeconomic crisis, as well as moderation, tracking weekly prices on a wide assortment of precisely defined grocery products from late 2003 to 2010 matched across Britain's three leading supermarket retailers. These three jointly make over half of all the grocery sales[1] and around a quarter of all the retail UK sales. This provides detailed insights into the mechanisms key firms used to respond to significant underlying cost changes both in stable times and the recent crisis. Our sample firms extensively used small price cuts, including many single penny cuts, as a competitive tool which could serve to distract attention from underlying upward movements in consumer basket prices and thus smooth resistance to rising prices.

Our analysis confirms most of the received facts of earlier micro-pricing studies in respect to the period 2003–7, but documents significant changes occurring over the turbulent years 2008–10, both in the frequency and character of the price changes. Price-setting behaviour does respond to macroeconomic drivers, at least those observed in the latter years of the

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[1] Magnitudes from Competition Commission (hereafter "CC") (2008). Other recent papers that have analysed cross-firm pricing in similar contexts include Kaplan and Menzio (2014), who focused on price dispersion, and Chevalier and Kashyap (2011) who focused on the consumers who shop across several outlets.

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first decade. As a result, the three supermarkets involved appeared to weather the storm of 2008–9 almost unscathed. Market shares held constant against competition, sales growth remained essentially unchanged and most significant for macroeconomics, margins on UK operations were essentially untouched[2] . Examining how they achieved this yields significant insights into the mechanisms behind the setting of nominal prices.

We focus attention on a key factor, namely that consumers buy baskets of goods rather than individual products when shopping at supermarkets, but may be influenced by claims regarding individual prices[3]. In particular, basket price rises are disguised in a very subtle manner, whereby more individual prices fall than rise, and yet most consumers actually pay a higher basket price. In other words, the episode investigated reveals and subsequently resolves an aggregation effect, most keenly seen from the inflationary period of early 2008, and is consistent with retailers aiming to obscure rising basket prices. Specifically, consumers may rationally be inattentive (Reis, 2006; Mackowiak and Wiederholt, 2009) to much of the detail on prices when searching for goods within supermarkets. As Chen et al. (2008) show, rational inattention is one explanation for asymmetric price adjustment. We prefer to refocus this as obfuscation, whilst accepting the difficulty in predicting the precise nature of micropricing based upon retailer obfuscation. Our argument is that in inflationary times sellers reduce resistance to price rises by flexing multiple prices including many downward movements.

Our price data have significant strengths, enhanced by certain unique features of supermarket price setting in Britain. The sample consists of actual shelf prices for a wide range of precisely matched grocery products across the three largest supermarket chains over seven years covering both the prosperous years of the earlier 2000s and the later turbulent years of 2008–10. A key feature is that all the three firms practise uniform national pricing across Great Britain (Competition Commission, 2008) within their large supermarket outlets, rendering the prices equivalent to individual store prices. This national pricing contrasts strikingly with local store-level pricing observed in the USA (Hosken and Reiffen, 2007; Ellickson and Misra, 2008), and with the "price flexing" formerly practised by Tesco and Sainsbury (Competition Commission, 2008; Smith, 2004) but abandoned to join Asda and Morrisons in national pricing by 2003 (Competition Commission, 2003)[4]. Hence we identify behavioural changes in price setting for a significant segment of the economy through a period of substantial macroeconomic change. To maintain absolute consistency, the focus is on 370 products matched both across time and supermarket chains. These cover all main grocery categories, with a wide range of brands and retailer's own label products, mainly processed products. This level of detail enables us to control for product type, brand origin and package size. Appendix 2 gives details on our data sources and our selection from them.

Supermarket purchases form a significant part of UK consumer spending and the companies involved are extremely professional. It has been estimated that the largest, the Tesco chain which had roughly 30% market share, accounts for at least 12% of British consumers' current expenditure (Verdict Research, 2008). Tesco was the world's third or fourth largest retailer by revenue (Deloitte, 2010); its rival Asda, with approximately 17% share of the British market, is a Walmart subsidiary. Sainsbury, the third largest (16%), is a long established national retailer. Price competition between them is significant. By matching across firms, indirect light is also cast on whether the common practice of using detailed data coming from a single store within an oligopolistic group might be misleading. As Nakamura (2008) points out, many existing studies are based on data from one supermarket chain, whereas her data and ours cover several store chains at a detailed level. In our case the major national chains are represented[5]. Moreover, in food and associated household good purchases, the consumer is buying a multi-product bundle, so there are additional considerations of behaviour within the menu of goods on offer.

Our sample relates most directly to that used by Ellis (2009), in being weekly (in line with consumer habits (Competition Commission, 2008, paras. 3.48 to 3.50)) and covering major UK supermarket chains, but we have more products and most importantly from the viewpoint of analysing significant macroeconomic episodes, his data stopped in early 2008. Yet the time period in 2008 where commodity price inflation was extremely rapid is of particular interest. Because of these supermarket chains' significance to the economy as a whole, their actions will impact significantly on the movement of retail price indices and so the transmission of inflationary processes nationally.

To preview results, we have three main findings. The key take-away (Section 2) is that despite there being substantially more price cuts than price rises, particularly through the most turbulent period, average prices rise over time in line with inflationary trends. This is because most price falls are very small indeed, commonly a single penny (Section 3). Second, Section 3 confirms most of the existing stylised facts; there is nothing peculiar about our data, nor indeed about the sector. Overlaid on that, there is a pattern of individual item price change markedly different from the regularity exhibited by Dominick's prices in the Chen et al. (2008) study. Third, Section 4 uncovers significant evidence consistent with obfuscation in the pricing behaviour. In addition in our sample, increases in typical basket prices are disguised by falls in large numbers

[2] Since around 2012 they have been affected by the growth of German discounters Aldi and Lidl, but within our period, competition remained largely within the group of major firms. Details of their sales, margins and shares positions are given in Appendix 1.

[3] Midrigan (2011) fully recognises that firms are multiproduct, but does not relate this specifically to the consumer side of the equation. An earlier empirical paper, Lach and Tsiddon (1996) also considers price setting by multiproduct forms, but does not link this directly to consumer purchase baskets. Kaplan and Menzio (2014) do consider consumer baskets of goods as an important element additional to individual product pricing.

[4] Tesco and Sainsbury operate more than one format and prices in their smaller in-town convenience stores, Tesco Metro for example, may diverge. Asda and Morrisons had no smaller stores. Most Tesco and Sainsbury sales take place in their larger stores.

[5] Surprisingly, there has been comparatively little investigation of pricing across sellers in determining price patterns over time outside of the energy prices, where there is a significant literature on "rockets and feathers" pricing mechanisms- Bacon, 1991; Bils and Klenow 2004; Borenstein et al., 1997; Zimmerman et al., 2011.

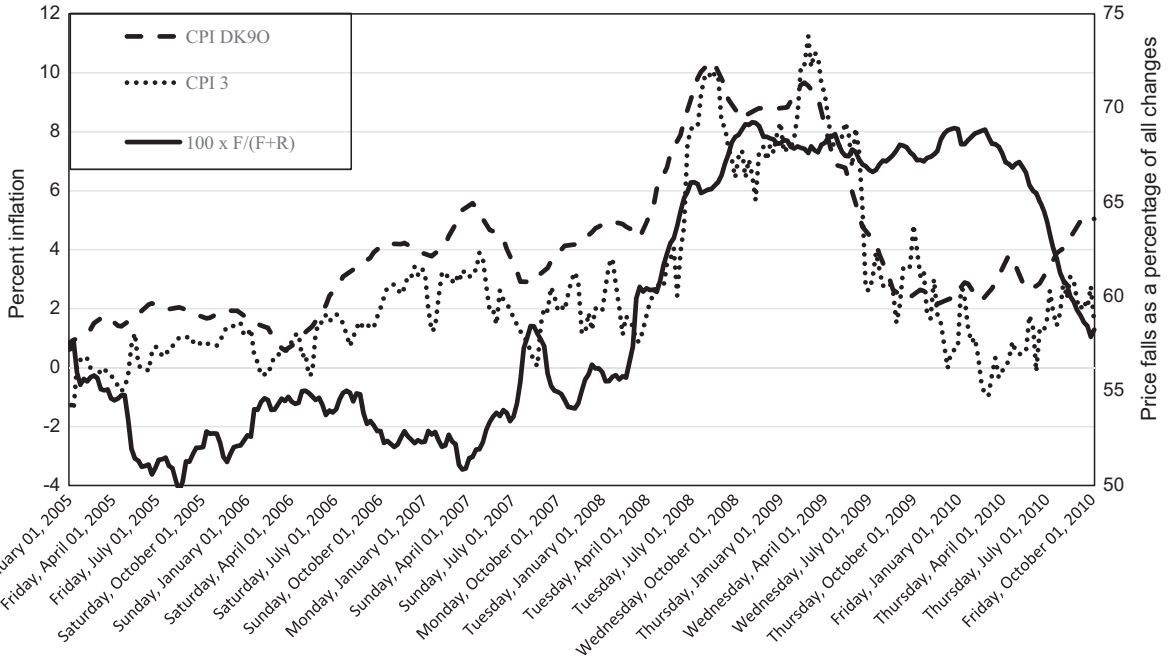


**Fig. 1.** Inflation comparisons, UK CPI and constructed 3 supermarket CPI together with percentage of price falls to total. Notes: (a)Inflation variables (CPI DK9O and CPI 3) plotted on left-hand vertical axis; per cent price changes that are falls (F) plotted on the right-hand axis. (b)Inflation measured by annual percentage change in monthly price index in each case. The UK consumer price indices (CPI) are available from ONS, DK9O relates to food, alcoholic beverages & tobacco and processed food & non-alcoholic beverages.

of individual item prices, making it significantly more difficult for the consumer to discern competitiveness in basket prices across chains. There are ten online appendices, as mentioned in the text.

## 2. Pricing movements: numbers versus impact

Fig. 1 plots three lines. It first establishes, that on average, price rises in our basket of products aggregated using CPI weights (dotted line) closely tracking the official food CPI (dashed line). Our key result is that despite this, throughout the period the number of product price *falls* relative to price rises plus falls (solid line, right hand scale) exceeds 50%. Moreover, the most inflationary period for supermarket prices coincides with the highest ratio of *falls* to rises, and (as shown in Appendix 3, Fig. A3a) also the largest absolute number of falls.

The macroeconomic backdrop to this is of course pivoted around 2008, following from the "great moderation", as a period of generally increasing prosperity. However, that calm period came to an abrupt halt in the first half of 2008 when retail food prices in the UK, as in many other countries, moved from gentle to rapid inflation, which was subsequently sharply reversed in association with the significant financial turmoil arising in the closing quarter of 2008. The scale of the inflationary impact on UK food prices is shown in Fig. 1 through the effect on the official CPI index. Substantial and widespread rises in world commodity prices in early 2008 (detailed in Appendix Fig. A3b) propelled increases in producer and consumer food price inflation. Despite large supermarkets having substantial buying power, world market trends will have forced all food retailers into real price increases, because even very large retailers like Tesco are small purchasers on a world scale. We focus on the mechanisms used to implement these retail price increases.

How robust is our key result that overall prices rise whilst more prices fall than rise? Because the analysis is performed on a relatively small sample of 370 products matched across Asda, Sainsbury's and Tesco, our sample is restricted amongst other things by the relatively narrow product range available. The collection of data over the Christmas/New Year period is limited and erratic, for all chains and products. Our product sample is chosen to maximise completeness of observation given this restriction. Pricing samples such as this commonly suffer from a degree of missing observations – e.g. Klenow and Kryvtsov (2008) and Nakamura and Steinsson (2008). Besides this problem, the data suffer from several difficulties that limit the sample, given our desire to make it as compatible and complete as possible. First, coverage of products particularly from fourth chain Morrisons is limited, forcing us to exclude it. Second, gaps appear from time to time, either because the operatives collecting prices were unable to find the product or because they was sold out. Third, the product mix sold in supermarkets does naturally change over time. Fourth, because the collection process is manual, occasional mistakes are made, such as prices which appear to be for a different quantity of the product. Our approach has been to drop products that do not appear initially, that leave the series before the end of 2008, or that have excessive gaps in the reporting period. To combine these various constraints, a Herfindahl-type approach was adopted (see Appendix 2). For these reasons elements of

**Table 1**
Correlations of price index differences over time, official and generated price index data.

| CPI measure | D7BT | D7BU | DK9O | DK9P | ASDA | Sainsbury's | Tesco | Ave | Wt ave |
|---|---|---|---|---|---|---|---|---|---|
| **D7BT** | 1 | 0.6925 | 0.721 | 0.6264 | 0.4228 | 0.6877 | 0.4806 | 0.4712 | 0.5455 |
| **D7BU** | 0.6925 | 1 | 0.9927 | 0.9398 | 0.8188 | 0.9417 | 0.8528 | 0.8395 | 0.903 |
| **DK9O** | 0.719 | 0.9927 | 1 | 0.922 | 0.8323 | 0.9365 | 0.8654 | 0.8457 | 0.9112 |
| **DK9P** | 0.6216 | 0.939 | 0.9215 | 1 | 0.6999 | 0.879 | 0.7429 | 0.7409 | 0.8006 |

*Notes*: Period covers November 2004 to November 2010, based on five week centred moving averages. Key to CPI measures: D7BT, D7BU, DK9O, DK9P are respectively: CPI all items index, Food and non-alcoholic beverages, Food, alcohol and tobacco, and Processed food and non-alcoholic beverages (Source: UK National Statistics Office). Our constructed indices for the three retailers mirror the construction of the official CPI measures in applying geometric means at the sub-COICOP level and weights from the CPI across COICOP (Classification Of Individual COnsumption by Purpose, a standard OECD/ ILO classification scheme) categories. The penultimate column Ave is a simple average of the three retailers, whereas "wt ave" weights the three retailers by their market shares.

our analysis were checked against a sample of 600 products drawn from the Tesco website data up until end 2008. None of the substantive conclusions are negated in this modified sample (see Chakraborty et al., 2011).

For much of our analysis, posted shelf prices are used, but occasionally there is more clarity in using "regular" prices, prices stripped of strictly temporary sales where the price reverts after six weeks or less to the exact same price; that is, using algorithm B of Nakamura and Steinsson (2008) in the form for weekly data adopted by Nakamura (2008). We call these "NSB prices"; still there are many more price falls than rises in the key period.

Table 1 examines the correlation between constructed quasi-CPI indexes using our samples and the most relevant official CPI series. To generate our indexes, for each supermarket we employed the official CPI weights and applied them to the geometric mean of the price observations within that category, subsequently aggregating up the relevant categories to the level of the CPI index[6]. Given the relative sparseness beyond processed products, and the high weights for alcoholic drink, four official CPI indexes are considered. The least relevant for present purposes is the headline CPI, given the nature of the products in our study, but the others are potentially closer, being focussed on food and drink in various ways. Correlations in price differences from the previous year are very high, those with the general index being the weakest, as can be expected. This confirms that our sample of prices over seven years exhibits a substantially similar pattern of price movements, of broadly similar character and extent to that shown by relevant CPIs, giving credence to our sample. To put it differently, someone buying the CPI basket but confined to our sample of products would face essentially the same inflationary pressures as if buying from all CPI basket products across the entire grocery market.

## 3. Representativeness of our sample

Should the macroeconomic community accept our finding of many small price cuts in the late noughties as a stylised fact? It would have little value if our sample turned out to be significantly idiosyncratic. We therefore check this possibility in three different ways. First, does our sample, particularly in its early period, fit with the stylised facts from studies in the past? Second, are there specific sectoral factors, as opposed to macroeconomic influences, which might account for the particular manner in which our firms compete? Third, how does the microstructure of pricing movements compare with the results in Chen et al. (2008), when mirroring their tests? In this section, confidence in our sample's properties in all three respects is demonstrated, but also substantial differences with Chen et al.

### 3.1. *Comparisons with other micropricing studies*

Apart from findings at variance with Chen et al. (2008), do our data fit with received facts on micropricing, or do we have a rogue sample? Two comprehensive surveys on pricing behaviour that provide a useful benchmark, the papers by Klenow and Malin (2011) and Nakamura and Steinsson ("NS") (2013), provide "facts" as listed in Table 2. Of these, almost all can be examined using our sample. As explained briefly below, a significant majority of these facts is found true also in our sample, at least for the moderation period of years 2004–2007.

KM's Tables 1 and 3 are comprehensive summaries of the extent of price flexibility. In this context, our prices change with average frequency, expressed on a monthly basis for the years 2004–2007 inclusive of 19.2 (14.2) per cent; the figure in brackets referring to "NSB prices". This fits tightly with the frequency of change of CPI data in the table for the UK (from Bunn and Ellis, 2009), and indeed most other European countries. It is substantially lower than the frequencies for scanner data, excepting Nakamura's (2008) NSB prices, but for reasons that are entirely understandable namely that have actual prices not average value indices (Eichenbaum et al., 2014). Thus KM Fact 1 (prices changing at least once per year) and Fact 2 (on sales being important for flexibility) hold true here. Whereas the mean duration of a price in our sample is 9.8 weeks,

[6] This conforms closely to the approach used in the UK to calculate the official CPI. The categories used are the standard COICOP (Classification Of Individual Consumption by Purpose, a standard OECD/ ILO classification scheme) categories; see also the discussion in Section 3.3.

**Table 2**
Examination of stylised facts from existing papers in the context of our sample.

| Fact | Description | True in our sample? |
|---|---|---|
| KM Fact 1 | Prices change at least once a year | Yes |
| KM Fact 2 | Sales and product turnover are often important for micro price flexibility | Yes |
| KM Fact 3 | Reference prices are more persistent than regular prices | Yes[a] |
| KM Fact 4 | There is substantial heterogeneity in frequency of price change across goods | Yes[a] |
| KM Fact 5 | More cyclical goods change prices more frequently | Yes (seasonal goods) |
| KM Fact 6 | Price changes are big on average, but many small changes occur | Yes (early period) |
| KM Fact 7 | Relative price changes are transitory | Some evidence of this |
| KM Fact 8 | Price changes are typically not synchronized over the business cycle | Yes |
| KM Fact 9 | Neither frequency nor size is increasing in the age of a price | Yes[a] |
| KM Fact 10 | Price changes are linked to wage changes | Not tested |
| NS Fact 1a | The median frequency of non-sale consumer price change is roughly half of what it is including sales | Yes[a] |
| NS Fact 1b | The median frequency of price change for finished-goods producer prices is comparable to that of consumer prices excluding sales | Not tested |
| NS Fact 2 | One-third of non-sale price changes are price decreases | Yes, though decreases more prevalent |
| NS Fact 3 | The frequency of price increases covaries strongly with inflation; the frequency of price decreases and the size of price increases and decreases do not | Our findings diverge from this, particularly later period |
| NS Fact 4 | The frequency of price change is highly seasonal; it is highest in the first quarter then declines | Seasonal, but not as pronounced |
| NS Fact 5 | No evidence of upward sloping hazard functions of price changes for individual products | Yes[a] |

*Notes*: KM refers to Klenow and Malin (2011) and NS refers to Nakamura and Steinsson (2013).
[a] means examined in detail for the same sample in Dixon et al. (2014).

the median duration is only 3.5 weeks (Dixon et al., 2014) so NS Fact 1 can also be accepted, and therefore also KM Fact 4, both being on heterogeneity in frequency across goods.

So as far as KM Fact 5, on cyclicality, is concerned there is no fresh produce in our main sample. However, it does include seasonal goods such as whisky, bought mainly in the winter period, which do fluctuate in price considerably. Relatedly, price changes take place throughout the year, rather than being synchronised (KM Fact 8). Yet, as NS Fact 4 suggests, the frequency of price change is certainly seasonal, although the pattern observed across months is not as clear as the one they report. Our early period certainly supports KM Fact 6: price changes are big in percentage terms on average, with many small (e.g. penny) changes. As detailed later, this character does change significantly in the crisis period. KM Fact 7 on relative price changes is best examined in our sample through examining branded and own label products of the same type; see Section 4.2. Suffice it to note here that there is some evidence of idiosyncratic price changes appearing to revert over time.

In respect of NS Fact 2, we find an even higher proportion of non-sale price changes being price decreases than they do, starting at around 50% in the moderation period and then growing much more rapidly in the crisis period, as seen in Fig. 1. Our finding on frequency of price increases and decreases and its link to inflation (NS Fact 3) is however rather different than in NS – of course in our sample there is a wider range of circumstances than a typical pricing study. This leaves three "facts"; KM Fact 3, in relation to regular prices, plus KM Fact 9 and NS Fact 5 which are essentially different ways of expressing the same point – namely that the hazard function of price change is downward sloping. These are outside the scope of the current paper but are shown to be true in our sample in a companion paper (Dixon et al., 2014, Table 3 and Fig. 3 respectively).

In addition, there is no indication from the considered stylised facts that our sample has anything unusual about it relative to the run of other papers in the pre-crisis period. However, various changes occur in our sample in the crisis period, as has been observed in studies of countries with high inflation episodes (Gagnon, 2009; Alvarez et al., 2013).

### 3.2. Market shakeups in the supermarket sector

Essentially, our claim is that changes we document in pricing behaviour are the result of macroeconomic pressures, namely the crisis. It is therefore important to demonstrate that there were no major changes in the industrial organisation or other aspects of the supermarket sector that might be alternative causes of the changed behaviour. Analysing the three most significant such events observed in the relevant period, none of them appear to be driving a change in pricing behaviour starting around 2007/8. One is a shock to industry structure, the second a Competition Commission market investigation, the third is changes in value added tax (VAT).

Prior to 2003, there were five major supermarket chains in Britain. Then a major market structure change occurred through the merger of Safeway (the UK chain) with Morrisons in late 2003, concluded in early 2004. This clearly had an impact, although market share data show that shares had consolidated by around the end of 2005. Thereafter, shares of all four major supermarkets, the three we examined plus Morrisons, remained remarkably static with no real trend: Tesco 30–32%, Asda 16–18%, Sainsbury's 15–17% and Morrisons 11–13% (source: Kantar WorldPanel, various dates). Moreover, as

shown by Chakraborty et al. (2014), the merger's main effect on pricing was on Safeway/Morrisons prices, which fell compared with the previous Safeway prices to rest at levels closer to the other three supermarkets (closest to Sainsbury's). The merger gave true national presence to all four major chains; previously Safeway was concentrated in the South and Morrisons in the North. This timing rules out a major merger-related change in competition between the three firms examined as between the earlier and later parts of our period.

The second candidate influence deserves a more detailed investigation, in part because of its timing. It is the Competition Commission (CC) investigation and report on the Grocery industry pursued over the period 2006–2008 (Competition Commission, 2008). Market investigations by the CC can and sometimes do result in substantial changes to an industry[7]. Therefore, it is possible that the grocery investigation led to substantive, perhaps implicit, impacts on the three firms. The most obvious way to investigate this is through an event study on stock-market prices. A drawback is that Asda, being a wholly owned subsidiary of Walmart, is not quoted separately. However, Tesco, Sainsbury's and Morrisons are all quoted on the London stock exchange, and in all cases, the British part of the business is the dominant element. We identified six events within our period that could be tied to particular narrow time windows[8]. These were the publication of (i) the CC's "emerging thinking" on 23/Jan/07; (ii) its Provisional Findings on 31/Oct/07; (iii) its "Provisional Remedies" document on 15/Feb/08; and (iv) its Final Report on 30/Apr/08; together with (v) the Competition Appeal Tribunal's (CAT's) upholding of Tesco's appeal against one of the proposed remedies on 4/Mar/09 and (vi) the CAT's remittal on 3/Apr/09 of the issue to the CC to reconsider that section of the report, together with its refusal for Tesco to appeal this remittal judgement on the same date. Using these six events plus the date of the final report on Safeway on 18/Aug/03, a variety of event studies was performed using standard techniques over the calendar years 2003 to 2013 inclusive, with the FTSE 100 index being the base comparator index[9]. Detailed results are reported in Appendix 4. In summary, there was no indication of an abnormal impact on share price returns of events (i) to (iii), nor of the earlier Safeway report. There was weak evidence of the Final Report having a *positive* impact on Tesco, if anything suggesting the market had expected more change than was actually proposed. Event (v) shows some evidence of a negative impact on Sainsbury's and Morrisons of the Tesco appeal, but no effect on Tesco, together with some indication that the Remittal (event vi) had a negative impact on Tesco and Morrisons. To us, this investigation suggests the CC report had no substantial impact on the (anticipated) subsequent market behaviour of the industry, either during or at the conclusion of the findings.

A third possible factor impacting on industry pricing behaviour is a sequence of two changes in VAT – the national value added tax – within our period. The first, coming into effect from 1/Dec/2008, reduced VAT from 17.5% to 15%; and the second, coming into effect from 1/Jan/2010, raised the tax to 17.5% again. Thus it is possible that increased pricing changes in these periods are related to tax changes. However importantly, food for human consumption plus some drinks including tea and coffee are zero-rated, so that approximately 119 of our 370 products are subject to VAT[10]. We focus particular attention on the period around these episodes. Certainly, the VAT reduction is associated with a local maximum in our data of price falls, and the VAT increase with a maximum of price rises. However, the overall picture is mixed. The first episode is also a local maximum of price *rises*, whereas the second is followed one week later with a count of price falls exceeding the rises in the VAT week. The rises are commonly much in excess of the tax incidence, whereas many of the movements relate to products where the tax regime is unchanged. Therefore, whilst the VAT changes had some effect on prices, these effects are not significant enough to disturb our conclusions regarding overall pricing behaviour.

So, the original finding remains. Prices definitely rose rapidly in 2008, particularly the earlier part, both in the CPI and in our sample. How did the firms involved manage to raise prices to consumers to such an extent whilst maintaining their competitive position against lower cost discount stores? And how did they do it whilst actually engaging in a welter of price cuts?

### 3.3. *Pricing microstructure and comparisons with Chen et al.*

Our key finding is that the number of price *falls* relative to rises is substantially higher in the later years of our sample and the proportion of falls to rises increases greatly (Fig. 1) when macroeconomic pressures are greater, yet basket prices rise over the period. The resolution lies in the relative monetary magnitudes of falls and rises. More basket component prices fall than rise in absolute number terms, but falls outweigh rises particularly for all the low values of pence, whereas price rises outweigh falls for almost all the intermediate values, namely from around 10p onwards. The picture on price falls is to a large extent a picture of penny price falls – Fig. 2 shows the extent of penny price falls in our sample.

[7] For example, a report on airports (Competition Commission, 2009) led to the breakup of the British Airports Authority in which London's three main airports, previously the same firm, were separated into three, with two sold to other parties.

[8] The decision to *refer* the industry for consideration by the CC is unsuitable for an event study, because it is something that becomes more or less probable over a period of several weeks.

[9] Dr Luigi Grossi kindly performed these event studies for us. We decided against including a sector index in addition to the FTSE100, on the grounds that to do so might minimise the impact of the report on the individual companies, because they jointly constitute such a large part of the relevant sector.

[10] The precise definitions at the margin are complex and not entirely logical, being determined by case law, so in a small number of cases it is difficult for us to know for certain how specific products are classified. For example, biscuits are not VAT-able, unless *entirely* chocolate-covered.

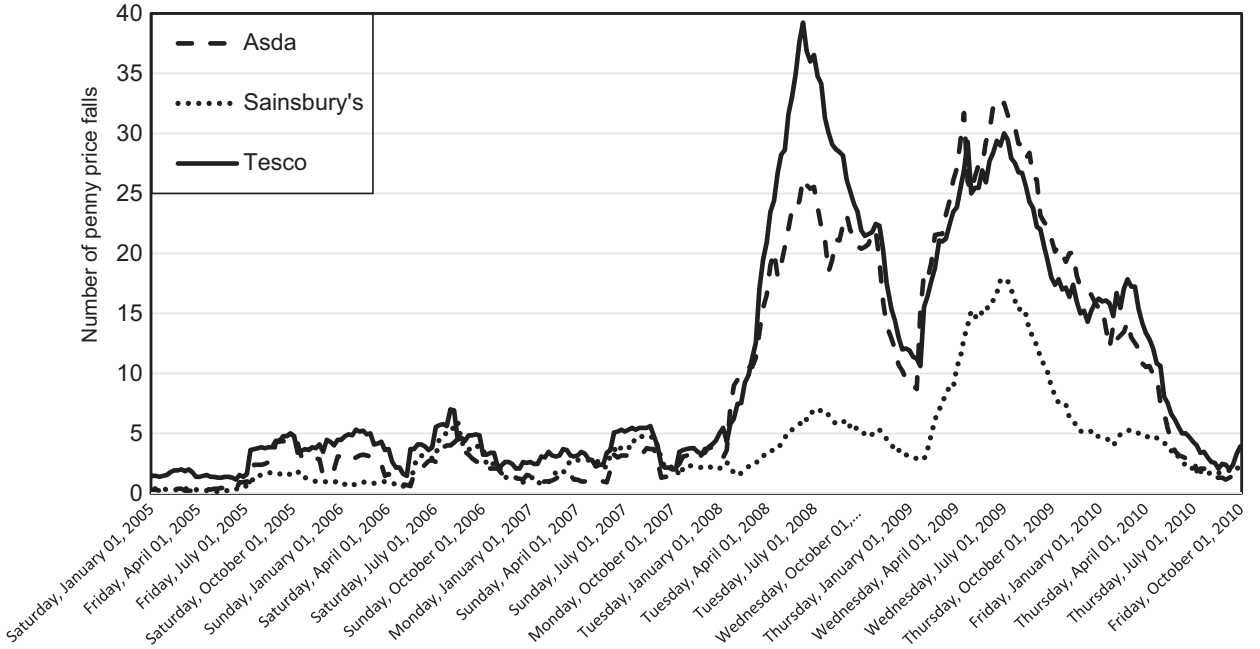


**Fig. 2.** Average numbers of penny price falls by retailer. Note: Quarterly centred moving average of the number of weekly penny price falls out of 370 products in each case.

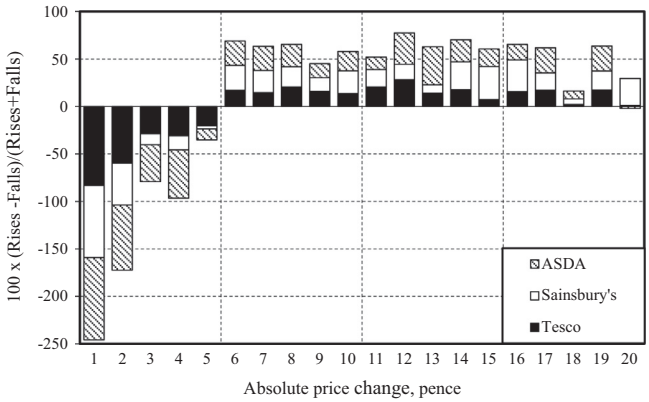


**Fig. 3.** Dominant price change proportions by absolute price change amount and retailer. Notes: a. Calculated from the number of X pence falls and X pence rises for each retailer in the entire dataset of 370 products. b. For each absolute price change, say Xp, the figure illustrates the relative dominance of price falls (negative values) and price rises (positive values) to total number of price changes. c. Potential maximum value for each retailer is 100, minimum value -100. Max (min) value obtained when all the price changes of that magnitude are positive (negative). Zero score implies equal numbers of falls and rises. The retailers' changes are summed for each pence change.

Fig. 3 focuses on micro movements up to 20p, examining each chain separately. To construct this, the price movements are scaled such that, if for any value of price movement each chain were making only price cuts, a value of -100 would be reached. If at that value of price movement each chain were only raising prices, then a value of +100 would be generated. Thus this figure shows both preponderance in direction and concordance amongst firms. As clearly seen, below 6p change, the price movements predominantly fall, whereas as one moves nearer to 20p, price movements are much more likely to be rising, although dominance here is not as strong as at the lower levels. The other object of significance is the extent of concordance between firms, although Tesco and Asda both engage much more extensively in penny price cuts than does Sainsbury's[11].

Because our headline findings on microstructure are precisely the opposite of Chen et al.'s (2008) findings for Dominicks' prices, it is important to check whether this is simply a difference of methodology or whether there are real differences in

[11] In the 600 product sample where Morrison's is included, it behaves more like Sainsbury than Tesco or Asda. Using a very different sample and methodology, Nakamura et al. (2011) also note differences across chains.

behaviour. Since there do seem to be real differences, it is important to investigate reasons for these. We examine our data using equivalents of the key tests employed by Chen et al., dividing our sample of products into categories, using the standard statistical COICOP categories, of which our products are represented in 13. Mean price and other key descriptives differ significantly across these categories; the lowest mean price being for vegetables (73 pence) and the highest for spirits (£13.78). Columns 1–2 in our Table 3 set out basic facts across our sample of products.

Chen et al.'s Table 3 is the core of their analysis. The third column in our Table 3 is an exact repetition of their method. Immediately, a key difference in results is apparent. Our table represents price *falls* down to which the equality of rises and falls can be rejected, whereas theirs represents price *rises*. In this respect, our results are completely opposite from theirs. Given this, it is important to engage in the intelligent equivalents of columns 4 to 6 of their table. They are concerned that inflation may be a cause of an excess of price rises, so they performed splits based upon examination. Our concern is more upon that the deflationary periods might cause an excess of price falls. Therefore, we separate out three subsamples: a deflation sample, a low inflation sample, and a high inflation sample. Monthly inflation of 0.2% was chosen as a cut-off rather than 0.1% because that would result in there being too few values in the category. Again, our results are almost precisely the opposite. Table 3 employs "stretched" and smoothed PPI values (stretched because the PPI data is monthly and our price frequency is weekly). A very similar set of results arises using stretched but unsmoothed data. One detail difference is that the number of pence (fall in our case) over which the null hypothesis of equal numbers of rises and falls can be rejected is smaller on average than in their case. Indeed, just examining the raw data, it is only up to around 6p that there is a statistical excess of price falls, in line with Fig. 3 given above.

Chen et al. then engaged in a number of robustness checks, for example basing it on inflation using CPI rather than PPI data. Our results on this (columns 7–9 of Table 3) show the same predominance of falls [12]. However, it is noteworthy that the CPI division leaves us with an excess of falls over rises statistically significant only for 1p for most of the categories in the deflationary period (the mean being 1.38p), and in the low inflation period (mean 2.15p) but up to 4.14p mean fall in the *inflationary* period, the opposite of what might be expected. We have insufficient sample size to examine individual years at the disaggregate product level for most categories, so cannot repeat this exercise in Table 3, but they note their results are a little more mixed in this case.

Thus whilst Chen et al. found that more small price changes were positive than were negative, we found the opposite, and equally strongly. How can these two findings be reconciled? There are several possibilities. First, however, despite the apparent contrast, both findings are consistent with a broad idea they put forward that consumers pay limited attention to supermarket prices, in the sense that they are pointed to particular changes that will likely take place, and through this the impact of other unwelcome price changes is reduced. In Chen et al.'s findings, this comes via highlighting large price falls, whereas in our paper, it comes through highlighting numbers of price drops. To develop our argument a little further, envisage a 3-by-3 payoff matrix representing, for simplicity, a symmetric two-player game. Each firm is confronted with the need to raise basket prices and has three possible strategies: one to make idiosyncratic large cuts; second to make many small cuts;third to increase prices by less but not to reduce any prices. Appendix 5 sets the game out in more detail, arguing that the last strategy is likely to be dominated and moreover that the game quite likely has two Nash equilibria, one where both firms make idiosyncratic large cuts, the other where they make many small cuts. Experimental work is consistent with this possibility[13].

Empirically, one of the observations our data enables is that supermarkets show some strategy differences, both across states of the economy and across supermarkets. It seems that Sainsbury's adopts a somewhat different strategy to Asda and Tesco, who take rather similar paths. In particular, Sainsbury's does not consistently have more prices falling than rising; in the early period it is somewhat the reverse, more like Dominicks. Also, by way of comparison, the market positioning of Sainsbury's in the UK is probably most similar to that of Dominicks in the Chicago area – somewhat upmarket of the mass operator(s) but not the top quality chain[14]. Sainsbury's does however change its pricing behaviour somewhat in the latter period of our sample.

More generally, one would expect that oligopolists' pricing behaviours will be influenced by their rivals and it is therefore useful to gain information from several chains. Given this, we explore whether our result survives (a) when confining our period of observation to the earlier years and (b) when examining the activities of individual firms. The final three columns of Table 3 report on these investigations, illustrating by product category; it uses a subset of the data reported in the earlier columns. Of course, slicing the sample means there is increased potential to encounter small sample sizes, and this limits our results. However, two things become clear. First, the results are less true of the early period than they are of our sample as a whole, although there is a persistent predilection, across time, firms and products, for single penny falls much to exceed penny rises. Second, Sainsbury's has a lesser tendency to engage in excess price falls than either of the others, this being consistent with Sainsbury's falls not outweighing rises in the early years and with our impression that Dominicks is more akin to Sainsbury's than to either of the other two.

[12] This uses the general CPI (code D7BT), that is the headline CPI that consumers would recognise, on the assumption that this is what influences behaviour. Previously, our comparisons between our prices and the CPI mainly employed food only CPIs, in order to compare like with like.

[13] Alba et al. (1999) carry out experiments to compare subjects' reactions to these two strategies specifically and find that either can dominate in consumers' minds.

[14] A *Chicago Sun-Times* retrospective on 30 January 2014 is our source for our remarks on Dominicks. Of course, shortly after the period studied in Chen et al., Dominicks was taken over by Safeway (the US chain) and ultimately collapsed in late 2013.

**Table 3**
Price fall in pence beyond which price falls do not significantly exceed rises.

| COICOP ID | Category description | 1 Number of observations | 2 Number of products | 3 Full sample | 4 PPI Deflation sample | 5 PPI Low inflation (< 0.2 pm) | 6 PPI High inflation (> 0.2 pm) | 7 CPI deflation sample | 8 CPI low inflation (< 0.2 pm) | 9 CPI High inflation (> 0.2 pm) | 10 Asda 2004–7 | 11 Sains 2004–7 | 12 Tesco 2004–7 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01.1.1 | Bread and cereals | 84,546 | 77 | 5 | 3 | 4 | 6 | 3 | 3 | 4 | 3 | 2 | 2 |
| 01.1.4 | Milk, cheese and eggs | 46,116 | 42 | 3 | 3 | 3 | 3 | 1 | 1 | 3 | – | – | 1 |
| 01.1.5 | Oils and fats | 21,960 | 20 | 6 | 3 | 5 | 6 | 1 | 3 | 6 | 3 | 1 | 3 |
| 01.1.7 | Vegetables | 27,450 | 25 | 3 | 3 | 3 | 6 | 1 | 1 | 3 | 2 | 1 | 2 |
| 01.1.8 | Sugar, jam, honey, syrups, chocolates etc | 36,234 | 33 | 4 | 3 | 3 | 6 | 1 | 3 | 4 | 1 | 1 | 1 |
| 01.1.9 | Food products (other) | 65,880 | 60 | 7 | 3 | 3 | 7 | 3 | 3 | 7 | 3 | 1 | 2 |
| 01.2.1 | Coffee, tea and cocoa | 18,666 | 17 | 3 | 3 | 3 | 5 | 1 | 1 | 3 | – | – | 2 |
| 01.2.2 | Mineral water, soft drinks and juices | 54,90 | 5 | 1 | 3 | 2 | 3 | 2 | 1 | 1 | 1 | 1 | 2 |
| 02.1.1 | Spirits | 23,058 | 21 | 9 | 4 | 5 | 9 | 1 | 5 | 8 | – | – | – |
| 02.1.3 | Beer | 10,980 | 10 | 1 | 3 | 3 | 4 | 1 | 1 | 1 | – | – | – |
| 05.6.1 | Non-durable household goods | 29,646 | 27 | 5 | 5 | 3 | 5 | 1 | 1 | 3 | 2 | 1 | 2 |
| 09.3.4/5 | Pets, related products and services | 20,862 | 19 | 6 | 3 | 3 | 6 | 1 | 4 | 6 | 1 | 1 | 1 |
| 12.1.2/3 | Appliances and products for personal care | 15,372 | 14 | 5 | 5 | 3 | 5 | 1 | 1 | 5 | 2 | 2 | 2 |
| | Total | 406,260 | 370 | | | | | | | | | | |
| | Average | | | 4.46 | 3.38 | 3.31 | 5.46 | 1.38 | 2.15 | 4.15 | | | |
| | Total weekly observations | | | 365 | 83 | 101 | 181 | 66 | 94 | 206 | | | |

*Notes:* COICOP - Classification of individual consumption according to purpose (a standard ILO and OECD classification scheme). Stretched and smoothed PPI or CPI values are used for classification purposes. These tables are calculated using similar criteria to Table 2 of Chen et al. (2008). Tests are *t* tests for significant difference between rises and falls. A number in columns 3–12 means that price falls up to that value significantly exceed price rises. For example, in column 3 the first value means price falls significantly exceed price rises up to the value of 5p for Bread and Cereals examined across the whole sample.

## 4. Can the observed price movements be attributed to obfuscation?

We propose that the peculiar patterns in price movements in our data, most obviously the large number of very small penny falls, are part of a mechanism to obfuscate or disguise underlying upward movements in prices that consumers will dislike. In this section, a variety of different pieces of evidence for our assertion are examined. For the most part, these in their different ways point strongly at the use of obfuscation.

First, what is obfuscation? Ellison, 2006 , pp.157–8 provided a useful summary of work on obfuscation relevant to our purpose and suggested, "The most straightforward way to think about obfuscation using standard IO tools would be to regard it as increasing search costs …". Other papers discussing the concept include Ellison and Wolitzky (2012), Piccione and Spiegler (2012), and Gabaix and Laibson (2006), who call it "shrouding". These papers demonstrate theoretically in various ways that the phenomenon exists in equilibrium and is not driven away by competition and they provide a few comparative statics. They are not written from a macroeconomic standpoint and do not deal in dynamics. In this section, a number of experiments are performed to evaluate whether obfuscation of price rises has occurred. However, we accept that obfuscation is more of a concept or range of activities than a predictive theory: Firms, facing potentially fierce competition,

engage in acts that soften price competition through making it more difficult for consumers to make comparisons. Thus more than one type of pricing behaviour is consistent with obfuscation, with the precise form dependent upon the circumstances.

### 4.1. Variance in the basket cost

Gabaix and Laibson (2004) consider obfuscation as "increasing the variance of the random evaluation error in a model in which consumers have noisy estimates of the utility they receive from consuming a product …" (quote from Ellison, 2006, p.158). In our context this could, for example, be noisy estimates of the price consumers pay for, and therefore net utility they gain from, the basket of products they purchase on any particular week. In the words of Gabaix and Laibson (2004, p. 3), "Higher levels of noise increases the chance that a consumer will either overestimate or underestimate the surplus associated with the firm's good. … [N]oise reduces … the elasticity of each firm's demand curve, leading firms to raise equilibrium prices." They show that when obfuscation is endogenous, firms respond to increased competition by increasing the level of noise (variance), which is what underlies their findings (Gabaix and Laibson, 2004; Gabaix et al., 2013; see also Perloff and Salop, 1985) that margins shrink only slowly as competitor numbers increase.

We select baskets of size 30 and size 50 then generate, with replacement, a random sample of 100 such baskets and track the mean and the variance of this distribution, for each week of our data across each chain. The random draw is weighted by *purchase frequency*; that is the choice of a particular product in the sample is proportional to the average frequency with which that product is purchased, in order that our constructed baskets map closely to real consumer baskets.

In our context, it is extremely plausible that the recession increased demand elasticities for food products[15], which would therefore reduce retailer margins ceteris paribus. A simultaneous increase in noise (variance) has the potential to restore margins to their existing level. We suggest that firms' selective promotions of low prices together with unannounced price rises provide the means by which the variance in the signal increases, increasing the degree of "product differentiation" between themselves, reducing the tendency for competition and cost pressures to drive down margins. Firms have greater incentive to do this when competition intensifies. The upper panel of Table 4 examines our contention that selective promotions, plus unannounced price rises, increase variance. Correlations between the standard deviation in the basket price and number of penny drops are always strongly significant and robust to basket size and definition of price.

In the lower panel of Table 4, the null hypothesis that there is no difference between basket mean prices across chains is tested against alternatives, across each week in the data. The natural alternative is one-sided – is my chain more expensive than the other? In the case of the basket size of 30, on all but two weeks of our sample, Asda is cheaper than Sainsbury. However, in only 10 of those weeks can the null hypothesis be rejected at the 5% level in favour of the alternative that Asda is cheaper. In 40 of our weeks, Asda is cheaper than Tesco. Nevertheless, the difference is small and never comes close to rejecting the null. Nor can the null in the Tesco-Sainsbury comparison be rejected. The power of the test naturally improves somewhat in the 50 item basket test. However, it never comes close to rejecting the null of equality between Tesco and Asda, and indeed the mean basket difference of 1.24% is small. Sainsbury is somewhat clearly uncompetitive on price, but other factors come into play as well in influencing the consumers' actual store choice. In addition, for a consumer with limited information about alternatives, the differences between the chains are seldom so stark that the consumer would be reasonably certain a chosen chain was uncompetitive. Two people, even with quite similar baskets, could easily come to legitimately different conclusions about which was the cheaper[16]. Nevertheless, purchasing a 50 item basket from Asda rather than Sainsbury would save over £200 a year.

### 4.2. Matched product subsample

Additional evidence consistent with obfuscation is provided by a matched product sub-sample. Within our sample of 370 products, there are 30 own-label products that tightly match 30 branded products, for example packets of own-label cornflakes and Kellogg's cornflakes of equal weight. This sample, although small, speaks to two issues. First, a plausible hypothesis is that consumers notice price changes, particularly increases, more on branded products than on their own-label equivalent. If so, at times of heightened awareness, price rises will focus on the own-brand version. Is this true in our sample? Second, do relative prices drift apart (which relates to KM Fact 7)?

Regarding the first question, the upper panel of Table 5 lists the percentage of price rises (or falls) that are on the branded products. Two features are worth highlighting. First, price rises are slightly more common in branded goods, across years and supermarkets. Second, price falls were heavily concentrated within the branded products in years 2008 and 2009 and, to a lesser extent, 2010. This is consistent with obfuscation, or at least limited attention, on the hypothesis that consumers are more attentive to price changes and promotions on brands. However it is also plausibly consistent with competitive behaviour. But do branded prices fall relative to own label?

[15] Taking a demand function for a normal good and assuming separability in price and income is sufficient to demonstrate an increase in price elasticity at any price following a fall in incomes.

[16] Of course, this test does not make comparisons with stores outside this set, for example the "hard discounters" which sell a more limited range of products.

**Table 4**
Correlations between numbers of penny drops and basket standard deviation by week

| **Basket size** | 30 | 50 | 30 | 50 |
|---|---|---|---|---|
| **Prices** | Posted | Posted | NSB | NSB |
| **Asda** | 0.320 | 0.317 | 0.370 | 0.317 |
| **Sainsbury's** | 0.390 | 0.390 | 0.363 | 0.380 |
| **Tesco** | 0.330 | 0.323 | 0.366 | 0.326 |

Testing if one supermarket's basket is cheaper than another

| **Tests of difference** | **Test** | **1 week** | | |
|---|---|---|---|---|
| | | **A < S** | **T < S** | **A < T** |
| **Basket size** | **30** | 10 | 0 | 0 |
| | **50** | 100 | 26 | 0 |

Null hypothesis: No difference in basket prices
One-way 5% test; 10 baskets per week observed

**Weekly basket price difference in £ (% in brackets)**

| | | | | |
|---|---|---|---|---|
| **Basket size** | **30** | 2.67 (4.36) | 1.91 (3.08) | 0.76 (1.24) |
| | **50** | 3.99 (4.15) | 2.80 (2.88) | 1.19 (1.24) |

*Notes:* "A" is for Asda, "S" for Sainsbury's and "T" for Tesco. Baskets are drawn randomly from our sample of 370 products, with the probability of choice corresponding to purchase frequency (shopping trips in which the good was purchased/total shopping trips). Numbers in the upper panel, to the right, refer to number of weeks (out of the total of 365) in which the null hypothesis of equal basket price, is rejected. NSB prices are prices generated using the Nakamura Steinsson (2008) Regular Price Algorithm "B".

On the second question, analysis of the matched samples suggests that pricing experience is extremely varied across the set of 30 products, a finding consistent with obfuscation. We ran separate regressions by product of the branded to own label price ratio across our whole period against dummies for 2008 and 2009, with summary results shown in the lower panel of Table 5. No clear general tendency is apparent. As can be seen, many price ratios rise over one or both years, many fall, and others show a mixed picture, with a slight tendency for the ratio to rise on average in 2008 and fall on average in 2009. Hence, despite the greatly increased numbers of price cuts on branded products, there is no trend to uniformly lower branded good prices in the 2008/9 period.

### 4.3. *Promotional pricing moves amongst the firms*

One advantage of our sample over most similar studies is that there are several firms to compare. It is possible that when observing small price changes the main driver behind them is in competition, not obfuscation. Indeed it is difficult to draw a bright line between obfuscation and competition, since obfuscation in Ellison and Ellison (2009) sense is a response to significant price competition. Here it is useful to think two types of price changes in the data. One is a "temporary price reduction" ("TPR"), defined as a price cut (of any amount) where the price returns to the same level within six weeks. The second type is a permanent price move, consistent with the NSB definition.

Price moves that are reciprocated in terms of direction[17] by other firms are potentially obfuscatory, but may also be (i) initiated by producers as a promotion strategy on their products, or (ii) competitive moves amongst suppliers. We focus attention on NSB price changes, and focus entirely on single penny cuts. There are three potential subcases: (a) I may drop my price when it is above the minimum offered by my competitors; this is clearly a potentially competitive move. (b) I may drop my price by 1p when it is already below the prices set by my rivals. There is no possible competitive reason for this, so such a small price fall must be viewed as obfuscatory, (c) I may drop my price when it is equal to the minimum set by my competitors, so that it undercuts them (albeit by a trivial amount). This might be seen either as competitive or obfuscatory. The analyses of Table 6 partially split this out for the three firms. It offers little evidence that Sainsbury adopts clearly obfuscatory price moves. However, there is some evidence that Tesco and, particularly, Asda do. For Tesco, the high point was 2008, for Asda it was 2009. Here, Asda is the most aggressive in cutting below its rivals; most ($\sim$ 70%) of its moves are in category (c), so they are related to "Price Check" strategies, but might be seen either as competitive or obfuscatory (consistent with Seaton and Waterson, 2013). More detail and raw figures are given in Appendix 6.

Our contention is that penny drops are designed deliberately as an obfuscation strategy, rather than a means of competition across firms. Note that if they were primarily a means of competition, their widespread adoption by all three

[17] For present purposes, we are deliberately using definitions that are broader than those in Seaton and Waterson (2013) in order to balance the scales against obfuscation.

**Table 5**
Percentage of price rises and falls attributed to branded items.

| | | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|
| Rises | Asda | 46.9 | 65.5 | 61.8 | 65.7 | 56.1 | 61.9 | 68.0 |
| | Sainsbury's | 43.9 | 63.2 | 52.5 | 59.0 | 57.0 | 60.4 | 59.1 |
| | Tesco | 46.5 | 58.7 | 59.7 | 55.6 | 53.8 | 57.5 | 58.1 |
| Falls | Asda | 50 | 52.8 | 68.2 | 57.0 | 82.0 | 86.1 | 73.6 |
| | Sainsbury's | 39.4 | 51.9 | 58.3 | 53.7 | 69.9 | 80.0 | 70.0 |
| | Tesco | 47.4 | 52.4 | 63.8 | 51.9 | 75.1 | 76.1 | 61.1 |

Significant dummy variables in a regression of branded to own label ratio by week on dummies for 2008 and 2009

| | Asda | Sainsbury's | Tesco |
|---|---|---|---|
| D2008 plus | 14 | 13 | 12 |
| D2008 minus | 9 | 6 | 9 |
| D2009 plus | 12 | 13 | 10 |
| D2009 minus | 13 | 15 | 16 |

*Notes:* Work is performed on parallel branded and own label product subsample (30 matched items in each sample) over the whole period. There are 30 separate regressions, one for each product. "D2008 plus" means a dummy taking on the value 1 in 2008 achieves positive significance at 5% level; other variables follow suit.

firms, particularly Tesco and Asda, would have led to observable drops in firm margins in the years 2008 and 2009. There is no sign (see Appendix 1) that this is the case. Rather, we suggest that they were targeted to create headlines.

To further characterise the situations in which penny drops were most prevalent, we ran regressions for each firm which included a set of explanatory variables, in addition to dummy controls for individual years, in order to "explain" penny drops across products. These were: whether the product is branded, if it was branded, size of the own-label share (by volume), whether the product was relatively highly priced in that firm and relative purchase frequency, i.e. the percentage of shopping trips in which it was purchased. The results are remarkably consistent across the firms and are reported in Appendix 7, Table A7.1. Including dummies interactive between the variables and years reveals that the effects are special to 2008 and 2009. Brand is (unsurprisingly) positive and significant, but so is own-label share. This means that brands were more targeted in areas where people are more likely to buy the own-label variant. Relatively lower-priced products were targeted as were those with a *lower* purchase frequency. This latter is very interesting: if directly aimed at competition, one would expect items that people buy more often to be more targeted. However, if creating publicity, then targeting products which are known but less often bought involves a lower potential downside for the firm.

Importantly, our data also clearly show that the penny drops we have documented are used by firms *alongside* the more traditional TPRs, rather than being substitutes. Indeed, correlations across years between penny drops and TPRs are high for each firm, at 0.837, 0.832 and 0.683 for Asda, Sainsbury, Tesco respectively. Yet they are targeted differently. Simple regressions, also reported in Appendix 7, Table A7.2, show that TPRs are used predominately on *more* frequently purchased *better-known* branded products of *higher* value. The strategies co-existed.

### 4.4. Advertising and consumer reactions

Our analysis so far suggests that the supermarket chains, particularly Tesco and Asda, were engaging in obfuscation of their true position that basket prices were rising, through the snowstorm of penny and other small value individual price falls that have been observed. Consistent with our view on obfuscation through promotion of price cuts, Nielsen Media/Mintel estimate that advertising spend in 2008 was up on 2007 by 28.3% for Tesco, 44.4% for Asda, 11.0% for Sainsbury's (see Appendix 8, Table A8.1). Nielsen does not provide a detailed breakdown on types of advertising. However, a source called visit4ads.com claims to record TV advertisements comprehensively (it does not cover other media). On inspection, their data are most complete for years 2006–2009 inclusive[18], so we draw comparisons between 2006/7 and 2008/9. Each of the approximately 1000 plus advertisements per firm per year was classified in a binary fashion as possessing or not possessing each of twelve features (e.g. did it advertise a price comparison). It is apparent from the results of this exercise, reported in Table 7 below and Appendix 8, that the categories "price image", "price comparisons" across stores, "cheaper than chain X" and "hundreds of price cuts" were used much more in the latter period, particularly by Tesco and (notably) Asda. Clearly, the thousands of tiny price cuts discussed earlier were also useful in making marketing claims about being competitive and keeping prices down, providing comfort to consumers and dampening their price sensitivity. There is market intelligence

[18] In Britain, the amount of advertisement time per hour in TV is regulated. Therefore, one would expect around the same number of advertisements recorded in total (across all products) per year. This is true in these four years, but in years either side of this, the recorded numbers are much lower in our source.

**Table 6**
Fraction by year of 1p NSB price moves that are below minimum other then drop further

| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | Average |
|---|---|---|---|---|---|---|---|---|
| **Asda %** | 2.4 | 5.5 | 0.9 | 12.9 | 12.4 | 16.8 | 6.1 | 12.7 |
| **Sainsbury's %** | 0 | 0 | 0 | 0 | 1.1 | 1.5 | 0 | 0.8 |
| **Tesco %** | 0 | 1.7 | 4.7 | 2.2 | 7.3 | 1.7 | 2.4 | 3.9 |

*Notes*: NSB prices are prices generated using the Nakamura Steinsson (2008) Regular Price Algorithm "B". "Below minimum other" means price is below either of the other two firms' prices before the drop takes place. The table refers to penny price drops only. All years are 52 weeks except that 2007 has 53 weeks and 2010 includes 44 weeks.

evidence that the pricing strategies plus marketing spend worked, in keeping consumers searching within rather than searching across supermarkets in pursuit of presumed value[19].

### 4.5. Do penny drops facilitate pass-through?

We examined the link between penny drops and pass-through by comparing weeks where the fascia's price rises are above those of the general CPI with weeks where the number of penny drops is above that company's average. The idea here is that each supermarket chain uses penny drops to differing extents. Sainsbury's uses them much less than Asda, for example. But if they are used to obfuscate, then an obvious target is to do this particularly when the company's prices are rising above the general level of (CPI) inflation. If so, there should be more cases where *relatively* large penny falls occur when the firm's inflation is above average than when it is below. More formally, our hypothesis is that the weeks of relatively intense price falls are *more* concentrated in weeks when the basket price rises more, the null being that relatively intense price falls are unrelated to the weeks when the basket price rise is above the CPI.

In our sample, there are respectively (134, 111, 148) weeks for (Asda, Sainsbury, Tesco) respectively out of 314[20] where the firms are raising their prices more quickly than the CPI. There are (105, 101, and 104) weeks where the firms' weekly penny price falls are more than the average number they perform. This means that if the above average penny rises across the weeks were randomly assigned, the probability that both events occurred in the same week would be (0.143, 0.114 and 0.156). The actual probabilities are (0.217, 0.175 and 0.242). Binomial tests force us to reject the null hypothesis in favour of the alternative at a very high degree of confidence. Therefore, it seems that the penny falls are likely to be obfuscatory.

In a variant test, we examined whether there was a correlation between the rolling 3 monthly average inflation for the supermarket relative to the relevant CPI index and the sum of penny drops over that rolling three month period. The correlations found for Asda, Sainsbury and Tesco respectively are 0.408, 0.432 and 0.198, respectively. All these values are significant at the 5% level or better. Thus, when inflation over the period was relatively high compared with food stores generally, the number of penny drops was relatively high. Taking both tests together, we conclude that the penny falls are likely to be obfuscatory.

### 4.6. Direct evidence through "left digit" effects

Our final and possibly strongest piece of evidence derives from the psychological literature and establishes a direct link between price rises and obfuscation. Increases in raw materials' prices of the magnitude experienced in early 2008 would have been extremely difficult for supermarkets to accommodate whilst maintaining leftmost price digits on retail prices and at the same time maintaining margins. The relationship between levels of leftmost digit changes and the number of small price reductions across our sample is close, indicating that noise is used to distract attention from price increases that would otherwise be noted by consumers.

There have been many studies, mostly experimental, in the area of consumer psychology investigating the left digit effect (e.g. Thomas and Morwitz, 2005; Stiving and Winer, 1997). The basic commonly confirmed finding is that consumers perceive the left digit in a price as more significant in comparing prices than the remainder of the digits[21]. The strength of the effect is such that we take it as a stylised fact and explore its implications for supermarket pricing policy. Supermarkets are not in the practice of trumpeting price increases; they may well find that, given an increase in a price from say 85p to 89p, few consumers notice. The left digit effect suggests this is the case, but also that an increase from 88p to 91p is much more likely to be noticed, although it is smaller. Yet in our data, whilst in the earlier years most price rises were small, less than 10p, in the latter period price rises in the range 10–20p became markedly more common, presumably because of sharp rises in wholesale costs, as documented in Appendix 3, Fig. A3b. So this implies that the challenge for a supermarket is how

[19] See Appendix 9 which collects market intelligence information on consumer attitudes on this point.

[20] A year's observations from the sample are lost when calculating annual inflation. These results refer to the complete baskets as in Section 2.

[21] Many of these studies are experimental, focused on prices ending in 9 or 99. They also focus either on accurate recall of individual prices or on contemporaneous comparisons of prices. In our case, the standard experimental assumptions are not exactly met – 9 endings are not overwhelmingly common in our sample and the appropriate comparison is between this week's price and the price last time the consumer shopped for the product.

**Table 7**
Patterns in advertising character across the firms.
Source: Authors' analysis of TV commercials stored by visit4ads.com

| | | Price promotion | Price image | Price comparisons | Cheaper than X | 100s of price cuts |
|---|---|---|---|---|---|---|
| **ASDA** | **2006–07** | 88 | 15 | 0 | 0 | 3 |
| | **2008–09** | 287 | 120 | 102 | 94 | 36 |
| | **Proportion** | 3.3 | 8.0 | | | 12.0 |
| **SAINS** | **2006–07** | 149 | 1 | 0 | 0 | 1 |
| | **2008–09** | 335 | 22 | 0 | 0 | 8 |
| | **Proportion** | 2.2 | 22.0 | | | 8.0 |
| **TESCO** | **2006–07** | 345 | 11 | 11 | 9 | 1 |
| | **2008–09** | 476 | 43 | 27 | 23 | 21 |
| | **Proportion** | 1.4 | 3.9 | 2.5 | 2.6 | 21.0 |

*Notes*: These results are based on a series of binary questions as to whether the advertisement includes the stated material. More details including the full list of questions are shown in Appendix 8.

to obfuscate or disguise such a price rise. One clear possibility, given our earlier findings, is to mask it through the welter of price falls, which commonly are trumpeted. This suggests a clear testable obfuscation hypothesis:

**Hypothesis L.** The number of a firm's *left digit rises* in prices each week is significantly correlated with the absolute number of price *falls* within our sample; the null being that there is no significant correlation.

Hypothesis L is examined using NSB prices, so as to focus on price changes that have some persistence. The results are easily stated and establish an interesting new statistic: The correlation between the number of left digit increases and absolute number of price falls across supermarkets per week is in the order (Asda, Sainsbury, Tesco), (0.450, 0.231, 0.487). All these are highly significant at conventional levels of significance, suggesting that obfuscation is being practised.

There are alternative theories that could link left digit increases and price falls. For example, Berger and Vavra (2015) demonstrated that the dispersion of price changes is large and countercyclical. When inflation is high, there will be more left digit rises; hence there is a plausible link between a large number of left digit changes and a greater number of price falls which does not require obfuscation as part of the explanation. However, the framework that Berger and Vavra develop does not incorporate asymmetries in the magnitudes of changes upwards and downwards, such as observed here. Therefore we refine our analysis by examining the relationship between left digit changes and *small* price falls specifically. There remains a significant correlation between the two series whether penny price falls only are considered or whether price falls in the range 1p to 5p are taken; the correlations across the three firms in this case are (0.301, 0.192, 0.340) and (0.430, 0.245, 0.490) respectively[22].

In summary, there are many separate pieces of evidence that point to or are consistent with price movements in our sample, in the 2008 and 2009 period in particular, being obfuscated through the mechanism of reducing many prices by a small amount, whilst increasing a smaller number of others by larger amounts. Several of our findings are difficult to explain through straightforward competitive behaviour. As a result of obfuscation, cost increases can pass through into basket price rises, without seemingly drawing the consumer's attention too obviously to what is happening.

## 5. Concluding remarks

Supermarket basket prices move in quite different ways from the prices of their constituent products, at least within our sample that encompasses the largest UK chains. Within our timeframe, there is one major inflationary then deflationary incident amid general mild inflation, and firms' pricing behaviours can be examined before, during and after this incident. Individual prices are very flexible, but more significantly, so are the basket prices. In particular, our study has shown that the period 2008–2009, where there were rapid cost movements in basic food commodities, was characterised by the UK supermarket chains raising basket prices. However the data is cut, what shines out is the core response, which we argue is consistent with attempts to obfuscate and hence to facilitate the fact that basket prices are rising and where the flurry of penny price drops coincided with intense marketing of "thousands of price cuts" and related retailer advertising claims. As a result, the supermarkets survived the macroeconomic turmoil relatively unscathed, with margins unaffected[23].

An obvious question is why, if tactics employed at the height of the crisis were successful, they are not employed all the time[24]. Our response is that presumably these tactics involve a cost – at least the cost of the pennies lost in revenue – and in less inflationary times could run the risk of triggering a genuine rather than a phoney price war or, with continued use, risk

[22] However, note for completeness that there is no significant correlation between the *difference* in Asda and Tesco's price cuts and the difference in their numbers of left digit price rises, for example. This suggests that this particular result does not extend to *relative* obfuscation across firms.

[23] The industry's trade magazine, "The Grocer", remarked in its issue of 18 July 2009 that "The UK's big four managed to dodge the cost of food inflation last year - by passing the full £5.7bn bill on to shoppers". This is consistent with the basic data set out in Appendix 1.

[24] A different, later, usefully complementary dataset we are exploring suggests that for fresh produce, whilst in the recession period there were many small price falls, these subsided in 2011 and after. See Appendix 10.

being exposed to consumers as a sham rendering them deeply suspicious of retailer announcements of "thousands of price cuts". Indeed, there was considerable negative media coverage when the penny drops ploy was exposed, late in the day. For example, "How Asda rolls back its prices - by a penny", *Daily Mail* 9/Mar/2009; "Half of Asda price cuts' worth just 1p′", *Telegraph* 9/Mar/2009; "The phoney supermarket price war", *Independent* 21/Nov/2009; "Every little helps? Supermarkets accused of 'cynical manipulation' over 1p cuts", *Guardian* 22/Feb/2010. However, media interest and consumers' memories tend to be short-lived, and the same ploy has been exposed before (e.g. "The price is wrong", *Telegraph* 7/Oct/2001) and so might be used again in the future. This suggests they will only be employed when the benefit exceeds the cost and risks attached.

In a contemporary report to the Treasury Select Committee, Bean (2011) (then Deputy Governor of the Bank of England) it was noted that one of the reasons CPI inflation experience in the UK has been markedly higher than the Bank had expected is that "… we appear to have significantly under-estimated the degree of pass-through from Sterling's 2007-8 depreciation …". Our work relates to this quite closely. The big rise in commodity prices in early 2008 largely came from overseas. Our paper exposes the behaviour of key players in the inflationary process in their desire and ability to raise prices in a competitive environment, hence providing some explanation for this changed outcome.

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## Appendix. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.jmoneco.2015.08.002.

## References

Alba, J.W., Mela, C.F., Shimp, T.A., Urbany, J.E., 1999. The effect of discount frequency and depth on consumer price judgements. J. Consum. Res. 26, 99–114.
Alvarez, L.J., 2008. What do micro price data tell us on the validity of the New Keynesian Phillips curve? Econ.: The Open-Access Open-Assess. E-J. 2. 2008–19.
Alvarez, F., Gonzalez-Rozada, M., Neumeyer, A., Beraja, M., 2013. From hyperinflation to stable prices: Argentina's evidence on menu cost models. Stanford Center for International Development, Working Paper no. 470.
Bacon, R.W., 1991. Rockets and feathers: the asymmetric speed of adjustment of UK retail gasoline prices to cost changes. Energy Econ. 13, 211–218.
Bean, C., 2011. Annual report to the Treasury Select Committee. Bank of England, London.
Berger, D., Vavra, J., 2015. Consumption dynamics during recessions. Econometrica 83, 101–154.
Bils, M., Klenow, P.J., 2004. Some evidence on the importance of sticky prices. J. Political Econ. 112, 947–985.
Borenstein, S., Cameron, A.C., Gilbert, R., 1997. Do gasoline prices respond asymmetrically to crude oil price changes? Q. J. Econ. 112, 305–339.
Bunn, P., Ellis, C., 2009. Price-setting behaviour in the United Kingdom: a microdata approach. Bank of Engl. Q. Bull. 9, 28–36.
Chakraborty, R., Dobson, P.W., Seaton J.S., Waterson, M., 2011. Pricing in inflationary times: the penny drops. Warwick economics research paper 975.
Chakraborty, R., Dobson, P.W., Seaton, J.S., Waterson, M., 2014. Market consolidation and pricing developments in grocery retailing: a case study. In: Pietz, M., Spiegel, Y (Eds.), , World Scientific, Singapore, pp. 3–29.
Chen, H., Levy, D., Ray, S., Bergen, M., 2008. Asymmetric price adjustment in the small. J. Monet. Econ. 55, 728–737.
Chevalier, J.A., Kashyap, A.K., 2011. Best prices. NBER working paper 16680.
Competition Commission, 2003. Safeway plc and Asda Group Limited (owned by Wal-Mart Stores Inc); Wm Morrison Supermarkets PLC; J Sainsbury plc; and Tesco plc: A report on the mergers in contemplation. HMSO, London.
Competition Commission, 2008. The Supply of Groceries in the UK. HMSO, London.
Competition Commission, 2009. BAA Airports Market Investigation. HMSO, London.
Deloitte, 2010. Global powers of retailing, London ⟨http://www.deloitte.com/assets/Dcom-Croatia/Local%20Assets/Documents/Documents-2009/hr_globalpowersofretailing2010.pdf⟩.
Dixon, H., Seaton, J.S., Waterson, M., 2014. Price flexibility in British supermarkets: moderation and recession. Warwick economic research paper 1041.
Eichenbaum, M., Jaimovich, N., Rebelo, S., 2011. Reference prices, costs and nominal rigidities. Am. Econ. Rev. 101, 234–262.
Eichenbaum, M., Jaimovich, N., Rebelo, S., Smith, J., 2014. How frequent are small price changes? Am. Econ. J.: Macroecon. 6, 137–155.
Ellickson, P.B., Misra, S., 2008. Supermarket pricing strategies. Mark. Sci. 27, 811–828.
Ellis, C., 2009. Do supermarket prices change from week to week?" Bank of England working paper 378. (⟨http://www.bankofengland.co.uk/publications/workingpapers/wp378.pdf⟩).
Ellison, G., 2006. Bounded rationality in industrial organization. In: Blundell, R., Newey, W.K., Persson, T. (Eds.), Advances in Economics and Econometrics, 2. Cambridge University Press, Cambridge, pp. 142–174.
Ellison, G., Ellison, S.F., 2009. Search, obfuscation and price elasticities on the internet. Econometrica 77, 427–452.
Ellison, G., Wolitzky, A., 2012. A search cost model of obfuscation. RAND J. Econ. 43, 417–441.
Gabaix, X., Laibson, D., 2004. Competition and consumer confusion. Mimeo.
Gabaix, X., Laibson, D., 2006. Shrouded attributes, consumer myopia, and information suppression in competitive markets. Q. J. Econ. 121, 505–540.
Gabaix, X., Laibson, D., Li, D., Li, H., Resnick, S., de Vries, C.G., 2013. The impact of competition on prices with numerous firms. Mimeo.
Gagnon, E., 2009. Price setting during low and high inflation: evidence from Mexico. Q. J. Econ. 124, 1221–1263.
Hosken, D., Reiffen, D., 2007. Pricing behavior of multiproduct retailers. B.E. J. Theor. Econ. 7 (Topics), Article 39.

Kaplan, G., Menzio, G., 2014. The morphology of price dispersion. NBER Working Paper 19877.
Kehoe, P., Midrigan, V., 2014. Prices are sticky after all. J. Monet. Econ. http://dx.doi.org/10.1016/j.jmoneco.2014.12.004.
Klenow, P.J., Kryvtsov, O., 2008. State-dependent or time-dependent pricing: does it matter for recent U.S. inflation? Q. J. Econ. 123, 863–904.
Klenow, P.J., Malin, B.A., 2011. Microeconomic evidence on price-setting. In: Friedman, B., Woodford, M. (Eds.), , Elsevier, Amsterdam, pp. 231–284.
Lach, S., Tsiddon, D., 1996. Staggering and synchronization in price-setting: evidence from multiproduct firms. Am. Econ. Rev. 86, 1175–1196.
Mackowiak, B., Wiederholt, M., 2009. Optimal sticky prices under rational inattention. Am. Econ. Rev. 99, 769–803.
Midrigan, V., 2011. Menu costs, multi-product firms and aggregate fluctuations. Econometrica 79, 1139–1180.
Nakamura, E., 2008. Pass-through in retail and wholesale. Am. Econ. Rev. 98, 430–437.
Nakamura, A.O., Nakamura, E., Nakamura, L.I., 2011. Price dynamics, retail chains and inflation measurement. J. Econ. 161, 47–55.
Nakamura, E., Steinsson, J., 2008. Five facts about prices: a re-evaluation of the menu costs model. Q. J. Econ. 123, 1415–1464.
Nakamura, E., Steinsson, J., 2013. Price rigidity: microeconomic evidence and macroeconomic implications. Annu. Rev. Econ. 5, 133–163.
Perloff, J.M., Salop, S.C., 1985. Equilibrium with product differentiation. Rev. Econ. Stud. 52, 107–120.
Piccione, M., Spiegler, R., 2012. Price competition under limited comparability. Q. J. Econ. 127, 97–135.
Reis, R., 2006. Inattentive consumers. J. Monet. Econ. 53, 1761–1800.
Seaton, J.S., Waterson, M., 2013. Identifying and characterising price leadership in British supermarkets. Int. J. Ind. Organ. 31, 392–403.
Smith, H., 2004. Supermarket choice and supermarket competition in market equilibrium. Rev. Econ. Stud. 71, 235–263.
Stiving, M., Winer, R.S., 1997. An empirical analysis of price endings with scanner data. J. Consum. Res. 24, 57–67.
Thomas, M., Morwitz, V., 2005. Penny wise and pound foolish: The left-digit effect in price cognition. J. Consum. Res. 32, 54–64.
Verdict Research, 2008. UK retail futures 2012: Food and grocery. Verdict, London.
Zimmerman, P.R., Yun, J.M., Taylor, C.T., 2011. Edgeworth price cycles in gasoline: Evidence from the United States. Rev. Ind. Organ. 42, 297–320.